Chapter 12

Zero Tillage or Reduced Tillage: The Key to Intensification of the Crop–Livestock System in Ethiopia

Jens B. Aune, Rahel Asrat, Dereje Asefa Teklehaimanot, and Balesh Tulema Bune

Numerous methods are available for increasing crop and livestock production in the Ethiopian highlands. Both national and international research institutes have developed technologies that are technically appropriate for these conditions. Examples of such technologies are the broad-bed maker for vertisols and cow traction (Zerbini, Woldu, and Shapiro 1999) and use of a single ox to pull the plow (Ouwerkerk 1990). However, farmers' adoption of these technologies has been very limited, and farming is still characterized in most areas by low input use and limited use of improved technologies. Fertilizer application has increased in recent years because improved crop production packages have been introduced through the Ethiopian extension service. Fertilizer has been easy to introduce because it does not require fundamental changes in the farming system. These packages have been accompanied by supply of credit. However, introducing these packages to farmers has not been without problems, particularly in dryland areas where crop failures are common. Farmers are often forced to sell animals to repay their debt. Despite these problems, it must be recognized that fertilizers do have an important role to play if farming in Ethiopia is to progress.

We believe that increased emphasis should be given to integrated approaches for agricultural development. There is a need to develop technologies and management schemes that can simultaneously enhance production, preserve the natural resource base, and reduce poverty. Different technological options have different effects. A pure fertilizer-based approach cannot address the problems of the poorer households and solve the problem of soil erosion, and a focus only on indigenous knowledge and low input use cannot generate sufficient growth. The crop–livestock system in Ethiopia is highly complex, with strong interlinkages between the crop and livestock components. These interlinkages are related to manure production, traction power, fodder production, and income generation. This makes it impossible to change one component of the system without affecting the others. More fundamental changes toward more productive crop–livestock systems therefore require an integrated and holistic approach. This chapter discusses the problems of the current crop–livestock system and suggests an alternative pathway for the crop–livestock system to enhance productivity and safeguard the environment.

Composition of the Livestock System in Ethiopia and Productivity Effects

The livestock production system in Ethiopia has low productivity. A survey in Tigray showed that average daily milk production in 8 *woredas* (administrative unit) per cow was 1.2 liters, and the average calving interval 27 months (Berhane 1996). Average productivity per animal slaughtered in Ethiopia is estimated to be 110 kilograms of meat and 213 kilograms of milk, and annual per caput consumption of milk and meat is estimated at 16 and 10 kilograms, respectively (Suttie 2000). In Kenya, by contrast, per caput milk production is 85 kilograms per year. This classifies Ethiopia as having the lowest per capita consumption of meat and milk, even among neighboring countries, although it has Africa's largest national herd (Bebe, Udo, and Thorpe 2002). We believe that one of the fundamental causes for the low productivity of the livestock system is the composition of the livestock herd. Studies of the livestock composition in different parts of Ethiopia show that there are often more oxen than cows (Aune et al. 2001). The composition of the livestock is a reflection of the production objectives of the livestock system (Ketelaars 1991), and for Ethiopia the dominance of oxen in the livestock system indicates that the primary output from the livestock system is traction power. The trend across different regions of Ethiopia is that farmers tend to retain oxen instead of cows when reducing the number of livestock (Aune et al. 2001). A survey in the Amhara region showed that the number of households owning oxen declined by 19 percent from 1991 to 1999, whereas the number of households owning cows declined by 35 percent during the same period (Jabbar and Ayele 2002). This shows an "oxenification" of the livestock system in Ethiopia. Cows are mainly used for reproduction purposes and to get some milk production in part of the year.

Several studies indicate that the composition of the herd in Ethiopia negatively affects the productivity of the crop–livestock system. A large survey in Tigray showed that the return to investment in livestock was 16 percent on average, whereas for cows it was 36 percent (Pender, Gebremedhin, and Haile 2002). Results from a crop–livestock model based on data from northern Gonder indicate that replacing oxen with milk-producing goats increases the profitability of the crop–livestock system (Ayele and Aune 2001).

This dominance of oxen in the current livestock system makes it difficult to introduce improved fodder management schemes because of lack of economic returns from oxen. A change in the composition of the livestock population will not occur unless the tillage system is modified because without oxen the land cannot be cultivated. If zero tillage or reduced tillage were introduced, farmers would have much less need to keep oxen for traction purposes. Replacing oxen with animals for meat and milk production may increase the overall productivity of the system.

Alternatives to Ox Tillage

Ox plowing in Ethiopia dates back to before 1000 B.C. The reasons for its widespread use in Ethiopia are cereal cultivation and particularly the cultivation of *teff,* which requires up to six passes with the *maresha* (the Ethiopian plow) and absence of the tse tse fly (causing tripanosomiasis) in the highland areas (Aune et al. 2001). However, this ox-plowing system that was appropriate in the past may not be the ideal system in the current situation characterized by smaller farm size and shrinking fodder resources as a result of rangeland degradation. A survey in the Amhara region confirms that farmers think that fodder resources are becoming increasingly scarce (Benin, Ehui, and Pender 2002; Chapter 6). Ox rental and sharecropping have also become more costly and more favorable to the ox owner. In northern Ethiopia increased use of half share of crop production to landowner and half share to tenant/ox owner has increased over the previous arrangement characterized by two-thirds to landowner and one-third to tenant/ox owner (Benin et al. 2005). Particularly female-headed households are in a weak position because it is culturally unacceptable for female farmers to plow with oxen in the Ethiopian highlands. Zero tillage is therefore particularly appealing for female-headed households.

Despite these constraints with the ox-plowing system, it remains the dominant tillage system. The alternative tillage systems that are being tested are reduced tillage and zero tillage. Reduced tillage is characterized by one pass with the *maresha* rather than the three to six passes in the conventional system. Zero tillage is without any plowing, and mulch application, herbicides, or manual weeding is used to control weeds. Studies by Sasakawa Global 2000 (an NGO), the Combating

Table 12.1 Effect of tillage system on maize yields, 1999 and 2000

Tillage system	1999 (213)	2000 (210)	Average
Conventional	4,944	4,387	4,670
Reduced	5,706	4,876	5,290
Level of significance	$P < 0.05$	$P < 0.05$	$P < 0.05$

Note: Number of participating farmers in parentheses.

Nutrient Depletion (CND) project, and a survey in Tigray (Pender, Gebremedhin, and Haile 2002; Chapter 5) illustrate that crop productivity can be increased by developing alternatives to the ox-plowing system. Promising results have so far been achieved with both maize and *teff.* However, the primary reason for introducing zero tillage or reduced tillage is not increased crop productivity but rather the possibility of replacing oxen with meat- or milk-producing animals.

Results from reduced tillage demonstration plots of Sasakawa Global 2000 in farmers' fields in 1999 and 2000, using herbicides to control weeds, show that yields are higher under reduced than under conventional tillage (Table 12.1). Average maize yield for the two years, based on 423 demonstration plots in the Oromia and Amhara regions, was 620 kilograms/hectare (Table 12.1) higher under reduced than under conventional tillage (Asrat 2002). Labor demand per hectare was 78 days lower under reduced tillage because of the savings on plowing and weeding. Cash expenditures are 550 birr/hectare higher under reduced tillage because of herbicide costs. However, if farmers would have to pay the labor cost for weeding and ox rental, cash expenditures would be 235 birr/hectare higher under conventional tillage. These estimates are based on the average wage rate in the area and labor demands in the two cultivation methods according to farmers' assessments. Herbicides were given freely to farmers in 1999 and 2000, and only 10 percent of the farmers continued to use reduced tillage when they had to pay for the inputs in 2001. The reasons given for this discontinuation were the high price of herbicides and the low price of maize. Other reasons are that farmers in these areas normally have access to a pair of oxen and low opportunity cost of labor. The value of the additional yield under reduced tillage is estimated at 248 birr/hectare based on a maize price of 0.4 birr/kilogram. Hence, it is not economically attractive for farmers to use reduced tillage if the saved labor has a low opportunity cost. At a maize price of 1 birr/kilogram, as in 1998–99 (Asrat 2002), the increased yield could pay for the herbicide costs. This underscores that an important factor demotivating the farmers to use reduced tillage is the low maize price. It will become even more attractive for farmers to turn to reduced tillage if they replace the oxen by animals for meat and milk production. Results from a survey in Tigray showed that reduced tillage is associated with 57 percent higher crop productivity than conventional tillage, controlling for labor and other input use, confirming that benefits from reduced tillage are likely (Pender, Gebremedhin, and Haile 2002; see also Chapter 5).

Experiments in the CND project in Gare Arere close to Ginchi in the central highlands show that zero tillage is also possible in *teff* (unpublished results). In this crop, up to six passes with the *maresha* are practiced. Results from 2001 showed that the average yield on a vertisol was 1,486 kg/hectare under zero tillage, compared to 1,424 under conventional tillage. Corresponding figures for a nitisol were 561 and 470 kg/hectare. No herbicides were used in these experiments, and weeding was done manually. The weed infestation did not differ significantly between the tillage methods. This indicates that annual application of herbicides might not be needed under some conditions or every year, and this can reduce the cost and risks of practicing zero tillage considerably.

Experiments across 10 years in Kulumsa, Ethiopia, also showed that zero tillage or reduced tillage is feasible in wheat (Taa, Tanner, and Bennie 2004). Wheat yield in zero tillage and reduced tillage were respectively 94 and 96 percent of wheat yield in conventional tillage.

Another benefit for farmers without oxen is that they can retain the entire production. Currently, they may have to pay about 50 percent of the yield for plowing, and the ox owner will, in addition, take the straw. This leaves farmers without oxen with very limited benefits. Moreover, they are in a weak bargaining position, without alternatives to ox plowing. Experience has shown that where alternatives to ox plowing exist, the cost of ox rental is lower (Aune et al. 2001). Zero tillage or reduced tillage offers such alternatives.

Oxen receive the best quality fodder before and during the plowing season. In Tigray, 68 percent of crop residues are fed to oxen (UNECA 1997). Hence, considerable scope for increasing livestock production exists if the scarce fodder resources could be used for milk and meat production rather than for traction purposes. It has been shown in Kenya that development of an intensive milk production system is feasible, even among smallholder farmers, with considerable increases in farmers' income (Bebe, Udo, and Thorpe 2002).

Zero tillage or reduced tillage will, in addition, contribute to reducing environmental problems, both locally and globally. Zero tillage can be as efficient as other soil and water conservation methods in controlling erosion, as shown in Nigeria (Lal 1984). Erosion rates in Ethiopia are currently alarmingly high in many areas because of the hilly nature of the terrain, and measures are necessary to halt the degradation of Ethiopian soil resources. Agricultural practices that mimic "mother nature" are the best practices from an environmental point of view. Continuous soil cover and an undisturbed surface layer with a high degree of recycling of plant nutrients characterize such production systems. The zero tillage system is an example of such a production system, as the soil surface remains undisturbed. Zero tillage or reduced tillage will also have a positive environmental effect globally by sequestering carbon. Zero tillage sequesters carbon because there is a lower decomposition rate of soil organic matter under zero tillage (Young 1997) and because zero tillage is associated with more recycling of organic matter. Higher carbon content of the soil is also associated with higher crop productivity in the tropics (Aune and Lal 1996). Increased humus content of the soil improves the water-holding capacity of the soil and improves soil surface characteristics (Pieri 1989).

Fodder Availability

A change in the composition of the livestock population should be combined with improved access to fodder of good quality and improved veterinary services. Improved breeds may in addition improve productivity. Several options are available for increasing the quality of fodder in Ethiopia. These include improved pasture management, growing of fodder crops and trees, and upgrading straw quality. A well-documented method for quality improvement of straw is treatment with urea (Suttie 2000). This method, widely used in China, is practiced in Ethiopia to only a limited extent. An economic assessment of the urea treatment technology in Ethiopia, using a crop–livestock model, has shown that each birr invested in urea treatment of straw yields a return of 5 birr when straw is fed to milk-producing goats (Ayele and Aune 2001). This is a particularly interesting option for Ethiopia, as straw is one of the major fodder resources in the highland areas (Jabbar and Ayele 2002). The importance of straw will probably increase in the future, as cropland is expanding at the expense of pastureland. The limited use of urea-treated straw in Ethiopia could be related to the composition of the livestock population because feeding urea-treated straw to oxen is expected to give very limited returns. Studies from India show that the adoption of urea treatment of straw depends on such factors as animal response, the price ratio between milk and urea, labor costs, access to water, availability of straw, and access and price of other fodder resources (Singh et al. 1993). This indicates that urea treatment of straw is most likely to develop in the vicinity of major markets.

Another low-cost method to increase straw quality without compromising grain yield is to harvest the grain at physiological maturity (30 to 40 percent grain moisture content) instead of at 10 to 13 percent, as normally is the case. Early maize harvest was shown to be associated with higher crude protein content and digestibility of straw in a study from southern Ethiopia (Tolera and Sundstøl 1999). Hay harvesting, widely practiced in Europe in former times, is another low-cost method for producing quality fodder.

Common and private grazing lands have been substantially reduced in the Amhara and Oromia regions, mainly because the area under cultivation has increased (Jabbar and Ayele 2002). Moreover, farmers are of the opinion that the productivity of the pastures has declined.

Better management of common grazing land can greatly contribute to increasing the quantity and quality of fodder. Establishment of area enclosures is a management practice that has proven successful in Ethiopia and particularly in Tigray. An area enclosure can be defined as an area that, for a given time period, is protected from grazing and human activities to allow regeneration of the vegetation. A study in Tigray has shown considerable benefits from area enclosures (Asefa 2001). Estimates based on counting bundles of grass from three different area enclosures showed that 3,200 kilograms of high-quality grass can be harvested per hectare from an area enclosure. A cow of 250 kilograms will need about 2,200 kilograms of dry matter per year. The grass can also be sold at the local market. The value of grass harvested from an area enclosure is about 1,850 birr/hectare. Surprisingly, this is equal to the average value of crop production in Tigray (Pender et al. 2002; Chapter 5). The costs of establishing and surveillance of the area enclosures are moderate. Demarcation costs of the area enclosures are about 186 birr/hectare of land. Each household spends about 5 birr/year for guarding the land. Establishing stone terraces within the area enclosures is estimated at 1,018 birr/hectare, assuming a wage rate of 7 birr/day, 800 meter long terraces per hectare, and one man building on average 5.5 m of terrace per day (Asefa 2001). Additional benefits of the area enclosures are increased biodiversity, less soil erosion, more continuous water discharge from the land, and increased honey production as a result of increased vegetation cover and more flowers. A survey in three villages has shown that 73 percent of the farmers in the area are in favor of establishing new area enclosures on their farms, whereas the other 27 percent objected. Those who responded negatively particularly mentioned reduced grazing land when new area enclosures would be established. Establishment of area enclosures will increase the pressure on adjacent grazing land. This may increase degradation of this area, but experience from Ethiopia (Asefa et al. 2003) and Tanzania (Sianga 1995) has shown that grazing land normally has a high degree of resilience, implying that the vegetation will soon recover if the grazing pressure is removed. More long-term negative effects are therefore not expected. Establishment of area enclosures has been found to be most beneficial in areas with intermediate population pressure (Gebremedhin, Pender, and Tesfay 2004; Chapter 10).

The area enclosures can alternatively be used for tree plantations, albeit at the expense of grass production. The value of grass production in an area dominated by trees was calculated at about 700 birr per hectare. Wood production from an area enclosure is estimated at about 250 m^3/hectare. A cubic meter of wood is sold for about 50 birr, which is equivalent to a value of about 12,400 birr 10 years after the establishment of the area enclosure. A study in the Central Ethiopian highland confirms that households can increase their income substantially by planting eucalyptus on land not suitable for crop production (Holden and Shiferaw 2002). Grass production will be reduced as the tree canopy develops.

Policy Implications

Crop and livestock production are closely integrated in Ethiopia; hence, changes in one component directly affect the other components of the system. We believe that adoption of the zero tillage or reduced tillage system could trigger a change in the crop–livestock system in Ethiopia. Development of zero tillage or reduced tillage is most likely to take place in areas with good market access. Evidence of this is that improved forage production in Holetta area in central Ethiopia was more widespread by farmers with dairy crossbred cows (Gebremedhin, Ahmed, and Ehui 2003). It will be impossible for most farmers to provide good quality fodder both for dairy cows and for oxen used for plowing. Development of dairy production is therefore incompatible with the traditional ox-plowing system. The traditional subsistence agricultural system including use of ox plowing is likely to prevail in areas with limited market access.

Currently the number of oxen is increasing relative to that of cows, and in many regions the number of oxen exceeds that of cows. This composition of the livestock system cannot pay for improved management of fodder resources. Hence, in areas with good markets for milk and meat production, there is an option to change the composition of the livestock accordingly. Development of zero tillage or reduced tillage without accompanying technologies does not suffice. Intensification of crop production will also be of benefit to livestock production. Increased straw yield as a result of crop intensification can be used as a basis for improving livestock production. In order to intensify crop and livestock production, there is a need to develop more site-specific fertilizer recommendations, identify crop varieties and livestock breeds that can profit from increased use of inputs, better veterinary services, appropriate residue management and hay cutting, and improved management of grazing land. However, such fundamental changes in the Ethiopian agricultural production system can take place only when backed by favorable economic policies and an effective extension service. This implies a more market-oriented approach of the farming systems in the Ethiopian highlands.

The policies that can trigger such a change in the agricultural system are favorable price policies for outputs and inputs and strengthening local institutions, particularly in the field of management of natural resources and purchase and sale of agricultural produce. Furthermore, emphasis should be given to the development of an adequate infrastructure, development of local credit institutions, and strengthening research and extension programs. It is particularly important that the government ensure a favorable relationship between grain prices and prices of inputs. This can partly be achieved by regulating import of grain and by encouraging and facilitating donors and NGOs to purchase locally produced grains in disaster situations. Such developments may be encouraged through use of cross-compliance, meaning that access to vital inputs such as credit for fertilizer can be made contingent on installing erosion control measures on eroded land, as proposed by Shiferaw and Holden (2000). Even though results of a household model have suggested favorable returns from such an approach, we believe higher returns can be expected if access to credit for crop and livestock production is made contingent on practice of zero tillage or reduced tillage and change in livestock production objective toward milk and meat. Such a policy measure should be explored, as that might also strongly reduce soil erosion and lead to increases in both crop and livestock production. Zero tillage might also be a more lasting solution to soil erosion control because the maintenance requirements for erosion control measures, such as terraces and stone bunds, are considerable. This approach will also contribute to sequestering soil carbon.

The economic factors that can change the crop–livestock system toward the use of zero tillage or reduced tillage are higher prices of cereals, meat, and milk products and higher opportunity cost for labor. These prices are normally higher in areas with good infrastructure or in the vicinity of urban centers. Prices of agricultural inputs will also be lower in such areas, and access to credit more easily available. Hence, it will be easiest to introduce zero tillage or reduced tillage in areas with good access to markets, and in an early phase of development of a new crop–livestock system, emphasis should be given to such areas. Zero tillage is now rapidly expanding in Latin America, where it is used on more than 14 million hectares (Derpch 1998).

The research and extension system should particularly focus on the development of an appropriate zero tillage or reduced tillage system and on upgrading the quality of straw. These can mutually support each other, thus contributing to the development of more sustainable crop production systems in the highlands of Ethiopia.

The suggestions above for policy changes are very much in line with the five *I*s that IFPRI has identified as factors that promote agricultural growth (Hazell 1999): innovations, infrastructure, inputs, institutions, and incentives. The UN Task Force on Hunger also emphasized improved soil fertility management and diversification of agricultural production with high-value products as key components to increased agricultural productivity for food-insecure farmers (Sanchez et al. 2005).

There is now a possibility through the Clean Development Mechanism under the Kyoto agreement for transfer of funds from OECD countries to developing countries as payment for carbon credits. Governments and community organizations can finance environmental rehabilitation activities and poverty reduction programs through agreements with industries in the North that need to buy quotas for CO_2 emissions. Such arrangements may, in the future, increase farmers' interests in establishment of area enclosures, if parts of the payment for the carbon credits are transferred to the rural communities. It might be possible, therefore, that carbon sequestration projects could finance land rehabilitation in Ethiopia. This is an option to explore in the future. The World Bank launched in 2002 the Community Carbon Fund and the Biocarbon Fund to facilitate the establishment of carbon sequestration projects. The objectives of these funds are to promote small-scale projects that can sequester carbon and at the same time promote sustainable development.

There is an increase in number of oxen to number of cows in Ethiopia, and this development pathway is opposite to agricultural intensification. We have found evidence that an alternative pathway may give increased food production while safeguarding the environment. Such a pathway is characterized by zero tillage or reduced tillage, milk and meat production, improved management of pastures and stover, and improved soil fertility. Such a development can be favored by appropriate price policies, access to credit, and a focus on these technologies in the Ethiopian research and extension system.